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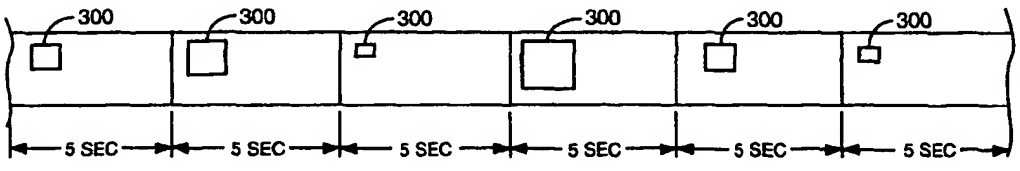
(54) Title: A SCALING INDEPENDENT TECHNIQUE FOR WATERMARKING IMAGES



(57) Abstract: A robust technique to prevent illicit copying of video information notwithstanding the use of image scaling is presented. A watermark is embedded into the video signal at different scales (i.e., sizes). The watermark is maintained at each scale for a predetermined time duration that is sufficient to allow the detector circuit in a digital format recorder to detect, extract, and process information contained in the watermark. At the end of the predetermined time duration, the watermark is changed to a different scale preferably on a pseudo-random basis to ensure that each one of all the scales in a predetermined scaling range is achieved a predetermined number of times. In this way, a particular scale that has the counter effect of restoring the watermark to its original position and size can be identified and used to allow the watermark to be detected.

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A SCALING INDEPENDENT TECHNIQUE FOR WATERMARKING IMAGES

FIELD OF THE INVENTION

The invention generally relates to copy protection and more particularly to a method to prevent the circumvention of watermarking copy protection by image scaling.

BACKGROUND OF THE INVENTION

Digital Versatile Discs (DVDs), which are a derivative of Compact Discs (CDs), are becoming increasingly popular as a media format for storing digital video and audio data. For reasons including greatly improved video and audio quality as well as improved reliability, the DVD format is gradually replacing the Video Home System (VHS) tape format as the preferred format for storing home video contents such as movies, etc. The technical superiority that makes DVDs attractive to the consumers also poses great concerns to the copyrighted content owners of the DVDs such as movie studios. This is because unlike analog copies, which are noticeably inferior to the original, a digital copy can be substantially similar in terms of video and audio quality to the original thereby making the unauthorized copying of the DVD contents too tempting to the average consumers. Such temptation can easily be realized once DVD-recorders, Digital-VHS (DVHS) recorders, Digital Video Cassette Recorders (DVCRs), and other digital format recorders which are now available for professional users, are made available at an affordable price to the average consumers in the not-too-distanced future.

A proposed solution to the problem of unauthorized copying (analog or digital) involves embedding hidden authentication information (e.g., a unique serial number, a transaction identifier, etc.) or hidden copy protection information (e.g., a copyright notice or others) in the original video during production. The hidden authentication and copy protection information, which may commonly be referred to as watermarks, are imperceptible to the naked

eye but may be detected using special circuitry and/or algorithms. The watermarks are embedded in the naturally occurring variations throughout an image and may be sufficiently robust to survive multiple generations of copying, modification, and compression. In its simplest implementation which is therefore easiest to detect and compromise, the watermark is appended to the original video as headers and trailers. In more sophisticated implementations, the watermark is distributed throughout the original video making it much more difficult to identify and eliminate the watermark. To prevent the illicit digital copying of DVDs, all DVD-recorders, DVHS recorders, DVCRs, and other digital format recorders conforming to this copy protection method include a detector capable of detecting the watermark embedded in the digital or analog video transmitted from a DVD-player playing a DVD or other video sources. Whenever such watermark is detected in the digital data stream, these DVD-recorders, DVHS recorders, DVCRs, and other digital format recorders are designed to shut themselves off thereby halting the illicit copying attempt.

However, an image scaling (i.e., sizing) feature may be soon made available as a standard feature in all DVD players to allow the physical scaling of the DVD video image. When the DVD video image is scaled up or down relative to a standard scale, a watermark may not be detected by DVD-recorders, DVHS recorders, DVCRs, and other digital format recorders. The reason is that a watermark is typically detected using predetermined X-Y coordinates relative to the horizontal and vertical sync pulses. Since the position and size of the watermark vary directly relative to image scaling, the predetermined X-Y coordinates may no longer be accurate in locating the watermark. Referring now to Figures 1A-1C illustrating as examples the variations in terms of position and size of an exemplary watermark due to image scaling. Figure 1A illustrates as an example the position (X,Y) and size (H,W) of exemplary watermark 102 relative to video image 101 and monitor screen 100 when video image 101 and watermark 102 are at a standard scale.

Figure 1B illustrates as an example the position and size of watermark 102 relative to video image 101 and monitor screen 100 when video image 101 and watermark 102 are at an arbitrary enlarged scale such that video image 101 fills up all of monitor screen 100. As shown in Figure 1B, in addition to being enlarged in size (H1,W1), the location (X1,Y1) of watermark 102 has been shifted relative to its previous positions shown in Figure 1A. Figure 1C illustrates as an example the position and size of watermark 102 relative to video image 101 and monitor screen 100 when video image 101 and watermark 102 are at a reduced scale. As shown in Figure 1C, in addition to being reduced in size (H2,W2), the location (X2,Y2) of watermark 102 has been shifted relative to its previous positions shown in Figures 1A and 1B.

As demonstrated by Figures 1A-1C above, the changes in position of a watermark due to image scaling may cause a watermark to go undetected. If the watermark is not detected by DVD-recorders, DVHS recorders, and DVCRs, they will not automatically shut off to prevent illicit copying thereby rendering the aforementioned method ineffective.

Thus, a need exists for a robust technique to prevent illicit digital copying of DVDs and other video sources using image scaling during the copying process without requiring added complex and costly hardware in the DVD-recorders, DVHS recorders, and DVCRs.

SUMMARY OF THE INVENTION

Accordingly, the present invention provides a technique to prevent illicit digital copying of DVDs and other video sources using image scaling during the copying process without requiring added complex and costly hardware in the DVD-recorders, DVHS recorders, and DVCRs.

The present invention meets the above need with a robust method to prevent illicit copying of video information such as DVD, digital broadcast video signal, etc. notwithstanding the use of image scaling. In accordance with the present invention, a range of scales

that a pirate is likely to use in image scaling is determined. Such a range of scales can be, for example, based on the picture quality such as loss of image details around the edges. Using this range of scales, a watermark having different scales is embedded into a video information stream according to a pattern. In particular, a watermark having a standard scale selected from the range of scales is first embedded in the video information stream for a first time period. During or at the end of the first time period, the watermark having another scale selected from the range of scales is embedded in the video stream for a second time period. The count of scales utilized is monitored. Using a different scale, the watermark is embedded. This pattern is repeated until the count reaches N number of scales. The objective of the present invention is that a watermark having an "inverse" scale can be identified and used to counter the effects of image scaling and restore the watermark to its original size and location thereby making it detectable by a typical watermark detector. Such detection triggers a recorder to shut off during an illicit duplication.

In one embodiment, for every 20 second interval, a watermark having a standard scale is embedded for 5 seconds to be followed by 3 watermarks with different scales for the next 3 5-second intervals. In so doing, the watermark having the standard scale is embedded throughout approximately ¼ of the duration of the video information and the watermark having other selected scales is embedded throughout the remaining duration of the video information. This ensures that any illicit duplication regardless of what image scale is used will be interrupted by a predetermined number of times throughout the duration of the video information. As an alternative embodiment, each selected scale is used in scaling the embedded watermark for a predetermined number of times thereby assuring that the digital recorder is shut-off that number of times.

All the features and advantages of the present invention will become apparent from the following detailed

description of its preferred embodiment whose description should be taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1A illustrates as an example the position (X,Y) and size (H,W) of exemplary watermark 102 relative to video image 101 and monitor screen 100 when video image 101 and watermark 102 are at a standard scale

Figure 1B illustrates as an example the position and size of watermark 102 relative to video image 101 and monitor screen 100 when video image 101 and watermark 102 are at an arbitrary enlarged scale such that video image 101 fills up all of monitor screen 100.

Figure 1C illustrates as an example the position and size of watermark 102 relative to video image 101 and monitor screen 100 when video image 101 and watermark 102 are at a reduced scale.

Figure 2A illustrates as an example the position (X,Y)and size (H,W) of exemplary watermark 202 relative to video image 201 and monitor screen 200 when video image 201 and watermark 202 are both at a standard scale.

Figure 2B illustrates as an example the position and size of watermark 202 relative to video image 201 and monitor screen 200 when video image 201 is at an arbitrary enlarged scale such that video image 201 fills up all of monitor screen 200 and watermark 202 is at a reduced scale that provides the counter effect of restoring the watermark to its original position and size in accordance with the present invention.

Figure 2C illustrates as an example the position and size of watermark 202 relative to video image 201 and

monitor screen 200 when video image 201 is at an arbitrary reduced scale and watermark 202 is at an enlarged scale that provides the counter effect of restoring the watermark to its original position and size in accordance with the present invention.

Figure 3 provides an illustration of a preferred watermark distribution pattern in accordance with the present invention.

DETAILED DESCRIPTION OF THE INVENTION

In the following detailed description of the present invention, numerous specific details are set forth in order to provide a thorough understanding of the present invention. However, it will be obvious to one skilled in the art that the present invention may be practiced without these specific details. In other instances well-known methods, procedures, components, and circuits have not been described in detail as not to unnecessarily obscure aspects of the present invention. Although the following description describes the present invention in the context of preventing illicit copying of DVDs, it should be clear to a person of ordinary skill in the art that the present invention can be used to prevent the illicit copying of any type of video information (analog or digital) from any video source (e.g., broadcast or cable-delivered video signal, video recorder, or others) to any digital format recorder.

In accordance with the present invention, the watermark is embedded by a watermark embedder during production into the DVD's content at different scales (i.e., sizes). The watermark is maintained at each scale for a time duration that is sufficient to allow the detector circuit in a DVD-recorder, DVHS recorder, DVCR, or any other digital format recorder to detect, extract, and process information contained in the watermark. During or at the end of a first time duration, the watermark is changed to a different scale (preferably on a pseudo-random basis) to ensure that each one of all the scales in a scaling range is achieved a N

number of times. In the preferred embodiment, the watermark is scaled to a standard scale (i.e., default scale) for a total duration that is approximately ¼ of the DVD's play length and at non-standard scales for the remainder of the DVD's play length. By ensuring that the watermark is scaled to substantially all values in a predetermined range, a particular scale that has the counter effect of restoring the watermark to its original position (relative to an absolute reference such as horizontal and vertical syncs) and size can be identified and used to allow the watermark to be detected by the detector resided in the DVD-recorder, DVHS recorder, DVCR, or other digital format recorders. Such a detection is used by the digital format recorder to turn itself off thereby preventing illicit copying.

Reference is now made to Figures 2A-2C illustrating as examples the counter effects of watermark scaling relative to image scaling in accordance with the present invention. Figure 2A illustrates as an example the position (X,Y)and size (H,W) of exemplary watermark 202 relative to video image 201 and monitor screen 200 when video image 201 and watermark 202 are both at a standard scale. A standard scale value is a default value that is predetermined by Original Equipment Manufacturers (OEMs) of DVD-recorders, DVHS recorders, DVCRs, or other digital format recorders. Figure 2B illustrates as an example the position and size of watermark 202 relative to video image 201 and monitor screen 200 when video image 201 is at an arbitrary enlarged scale such that video image 201 fills up all of monitor screen 200 and watermark 202 is at a reduced scale that provides the counter effect of restoring the watermark to its original position and size. As shown in Figure 2B, despite the enlarged size of video image 201, watermark 202 has been restored to its original position (X,Y) and size (H,W) shown in Figure 2A. Figure 2C illustrates as an example the position and size of watermark 202 relative to video image 201 and monitor screen 200 when video image 201 is at an arbitrary reduced scale and watermark 202 is at an enlarged scale that provides the counter effect of restoring the

watermark to its original position and size. As shown in Figure 2C, despite the reduced size of video image 201, watermark 202 has been restored to its original position (X,Y) and size (H,W) shown in Figure 2A.

As demonstrated in Figures 2A-2C, to restore the watermark to its original position and size, the watermark scaling is "inversely" related to the image scaling. For example, if the image is enlarged by +10%, the watermark needs to be reduced by -10% if its position and size are to be restored to their original values. Similarly, if the image is reduced by -10%, the watermark needs to be enlarged by +10% if its position and size are to be restored to their original values. Accordingly, it is desirable under the present invention to make sure that the watermark is scaled a predetermined number of times at substantially all possible values in a scaling range so that a particular "inverse" scaling value can be identified and used by the watermark to counter the effects of image scaling to bypass the watermark by a DVD content pirate.

In the preferred embodiment, a scaling range of ±20% relative to the standard scale is implemented. Empirical data indicates that an enlargement of greater than +20% relative to the standard scale is likely to cause significant details to be lost around the edges of an image and is therefore, not likely to be implemented for illicit copying. Similarly, a reduction of greater than -20% relative to the standard scale is likely to cause an undesirable big black border around the image as well as to make an image too small for viewing and is therefore, not likely to be implemented for illicit copying. However, it is to be appreciated that other scaling ranges may be used and still be within the scope of the present invention. Because a typical watermark detector has a resolution of ±0.25%, a scaling step of ±0.4% is implemented in the preferred embodiment to provide a margin against overlapping. It is to be appreciated that other scaling steps may be employed as well and that a variable scaling step can also be implemented in the present invention. With

a scaling range of ±20% and a scaling step of ±0.4%, there are a total of 100 non-standard scales in the preferred embodiment. From these, it is highly likely that one of the non-standard scales will be the "inverse" to the scale that is used in image scaling. As discussed above, when the watermark is scaled by such "inverse" scale factor, the location and size of the watermark is restored to its original value thereby allowing the watermark detector to detect the watermark.

Moreover, a typical watermark detector requires as much as 5 seconds to detect, extract, and process the information in an embedded watermark. As such, each scaling step needs a minimum duration of 5 seconds in the preferred embodiment. It is to be appreciated that this minimum duration is subject to change as improved watermark detectors are introduced. In the preferred embodiment, it is also desirable for the watermark to have a standard scale for ¼ of the DVD total play length. This is designed to provide the sufficient number of interruptions (i.e., recorder shut-off) to discourage illicit copying in the event no image scaling feature is available in the DVD-recorder, DVHS recorder, DVCR, or other digital format recorder. The remaining ¾ of the DVD total play length is dedicated to the other (100) non-standard scales. It should be clear to a person of ordinary skill in the art that other ratios can also be used. As an example, for a 2 hour long movie, there are 360 times (1800seconds/5seconds=360) that a standard scaled watermark appears and 1080 times (5400seconds/5seconds=1080) that a non-standard scaled watermark appears through out the movie. Because there are 100 non-standard scales, the watermark appears at each non standard scale at least 10 times through out the movie. This means that there are at least 10 interruptions in an illicit copying attempt each of which requires a pirate to get up, rewind the discs, adjust the image scaling to a new scale value, and then push record. Such a major inconvenience likely discourages most home illicit copying attempts.

In the preferred embodiment, to evenly distribute the standard scaled watermark throughout the movie, for every 20 second interval, a standard scaled watermark is embedded into the video/audio data content of the DVD for 5 seconds followed by 3 5-second or other duration periods of arbitrary non-standard scaled watermarks. The pattern is then repeated for the next 20 second interval but with different scales selected for the non-standard scaled watermarks. The non-standard scaled watermarks are randomly selected for each movie to make it difficult to determine where in what movie a particular watermark scale occurs. This pattern is based on the ratio of the total duration of embedded standard scaled watermark versus non-standard scaled watermarks. Figure 3 provides an illustration of this watermark distribution pattern. In Figure 3, a sequence of video data frames along a time line (representing DVD content information or other video sources) are illustrated wherein a watermark is shown embedded into each data frame. For convenience, each data frame is assumed to have a duration of 5 seconds. As shown in Figure 3, the watermark 300 sizes are different between frames. The first data frame has a watermark at a standard scale and the subsequent frames have watermarks with randomly different scales. This pattern is repeated throughout the duration of the video information (e.g., DVD's content length or other video sources).

It is to be appreciated that other patterns are also within the scope of the present invention. Because the standard scaled and non-standard scaled watermarks are embedded into a DVD or any other video sources during its production by a professional watermark embedder, no additional hardware is required in a recorder which greatly reduces the cost of the recorder thereby making it more attractive for recorder OEMs to participate in a proposed copyright protection scheme. It should be clear to a person of ordinary skill in the art that the watermark embedding process is well-known and the watermark embedders used for this process are well-known and readily available

commercially. As such, they are not further discussed here for simplicity sake. Because a professional watermark embedder costs a few thousand dollars, any costs imposed by the present invention to these machines are insignificant.

The preferred embodiment of the present invention, a technique to prevent illicit copying of video information such as DVDs or other video sources notwithstanding the use of image scaling, is thus described. While the present invention has been described in particular embodiments, the present invention should not be construed as limited by such embodiments, but rather construed according to the below claims.

CLAIMS

What is claimed is:

1. A method to prevent illicit copying of video information comprising:

a) embedding a watermark having a first scale selected from the range of scales in the video information for a first time period;

b) during or at the end of the first predetermined period, embedding a watermark having another scale selected from the range of scales in the content of the video information for a second time period; and

c) repeating step (b) using a different scale until a N number of scales is reached.

2. The method of claim 1 further comprising the step of repeating steps (a)-(c) throughout part or all of the video information.

3. The method of claim 2, wherein the watermark having the first scale is embedded throughout approximately ¼ of the duration of the video information and the watermark having other scales is embedded throughout the remaining duration of the video information.

4. The method of claim 1 further comprising the step of repeating step (c) until each scale is used in scaling the embedded watermark for a predetermined number of times.

5. The method of claim 1, wherein each scale is randomly selected in step (b).

6. The method of claim 2, wherein the range of scales is ±20 percent relative to the first scale.

7. The method of claim 5, wherein the N number of scales is determined using the range of scales and watermark detection resolution of a watermark detector.

8. The method of claim 2, wherein the first time period is based on the time required by a watermark detector to detect, extract, and process the watermark.

9. The method of claim 1, wherein the source of the video information is a Digital Versatile Disc (DVD).

10. The method of claim 1, wherein the source of the video information is broadcast, cable-delivered, or internet-delivered video signals.

11. The method of claim 1, wherein the first time period is substantially the same as the second time period.

12. The method of claim 1, wherein the first time period is different from the second time period.

13. A record carrier storing a content, the record carrier having a watermark at different scales embedded into the content according to a pattern such that the watermark having a first scale selected from a range of scales is embedded in the content of the record carrier for a first time period, during or at the end of the first time period, a watermark having another scale selected from the range of scales is embedded in the content of the record carrier for a second time period, subsequent watermarks having different scales are similarly embedded in the content until N number of scales is reached.

14. The record carrier of claim 13, wherein the embedded watermark pattern is repeated throughout part or all of the content duration of the record carrier.

15. The record carrier of claim 14, wherein the watermark having the first scale is embedded throughout approximately ¼ of the content duration and the watermark

having other scales is embedded throughout the remaining duration of the content.

16. The record carrier of claim 13, wherein the embedded watermark pattern is repeated until each scale is used in scaling the embedded watermark for a predetermined number of times.

17. The record carrier of claim 13, wherein each scale is randomly selected.

18. The record carrier of claim 14, wherein the range of scales is ±20 percent relative to the first scale.

19. The record carrier of claim 18, wherein the N number of scales is determined using the range of scales and watermark detection resolution of a watermark detector.

20. The record carrier of claim 11, wherein the first time period is based on the time required by a watermark detector to detect, extract, and process the watermark.

21. The record carrier of claim 13, wherein the digital record carrier is a Digital Versatile Disc (DVD).

22. The record carrier of claim 13, wherein the first time period is substantially the same as the second time period.

23. The record carrier of claim 13, wherein the first time period is different from the second time period.

24. A signal carrying video information embodied in a propagation medium, the video information signal having a watermark at different scales embedded into the video information according to a pattern such that the watermark having a first scale selected from a range of scales is embedded in the video information for a first time period,

during or at the end of the first time period, a watermark having another scale selected from the range of scales is embedded in the video information for a second time period, subsequent watermarks having different scales are similarly embedded in the video information until N number of scales is reached.

25. The video information signal of claim 24, wherein the embedded watermark pattern is repeated throughout part or all of the duration of the video information.

26. The video information signal of claim 25, wherein the watermark having the first scale is embedded throughout approximately ¼ of the duration of the video information and the watermark having other scales is embedded throughout the remaining duration of the video information.

27. The video information signal of claim 26, wherein the embedded watermark pattern is repeated until each scale is used in scaling the embedded watermark for a predetermined number of times.

28. The video information signal of claim 24, wherein each scale is randomly selected.

29. The video information signal of claim 25, wherein the range of scales is ±20 percent relative to the first scale.

30. The video information signal of claim 29, wherein the N number of scales are determined using the range of scales and watermark detection resolution of a watermark detector.

31. The video information signal of claim 25, wherein the first time period is based on the time required by a watermark detector to detect, extract, and process the watermark.

32. The video information signal of claim 24, wherein the video information signal is a broadcast, cable-delivered, or internet-delivered video signals.

33. The video information signal of claim 24, wherein the first time period is substantially the same as the second time period.

34. The video information signal of claim 24, wherein the first time period is different from the second time period.

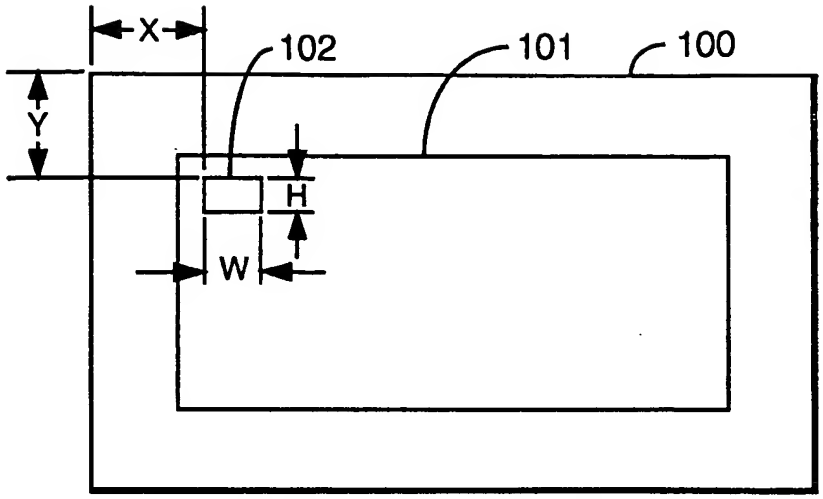

FIG. 1A

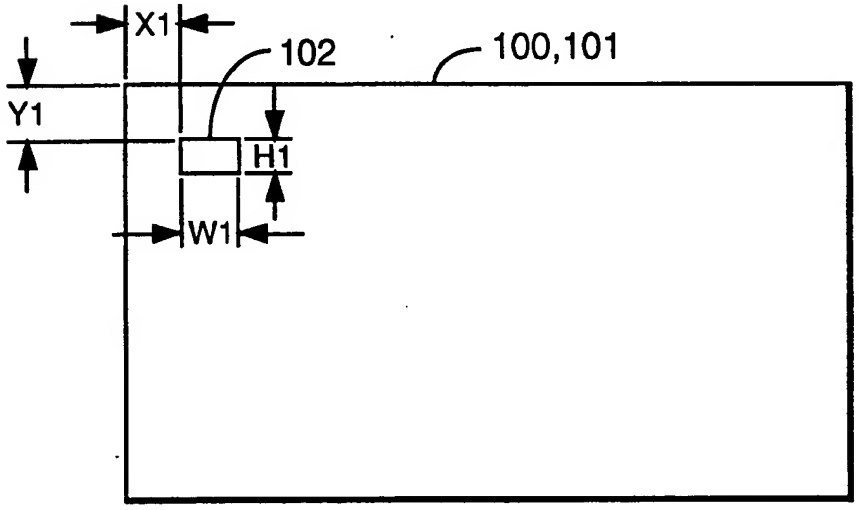

FIG. 1B

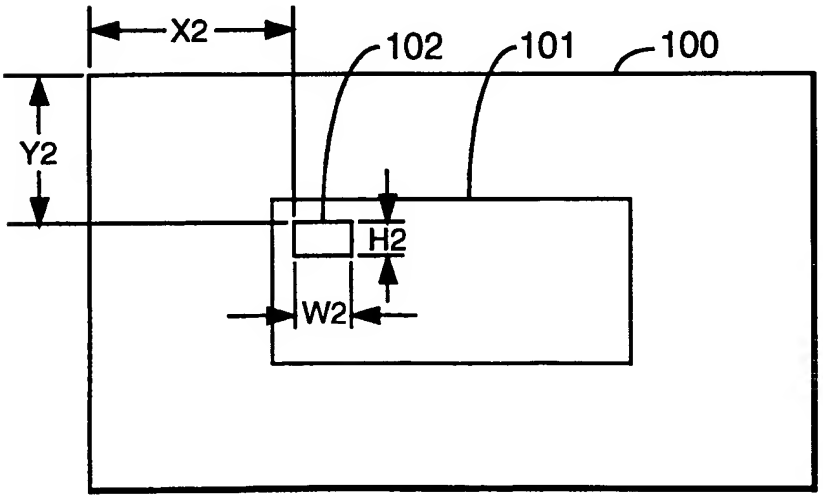

FIG. 1C

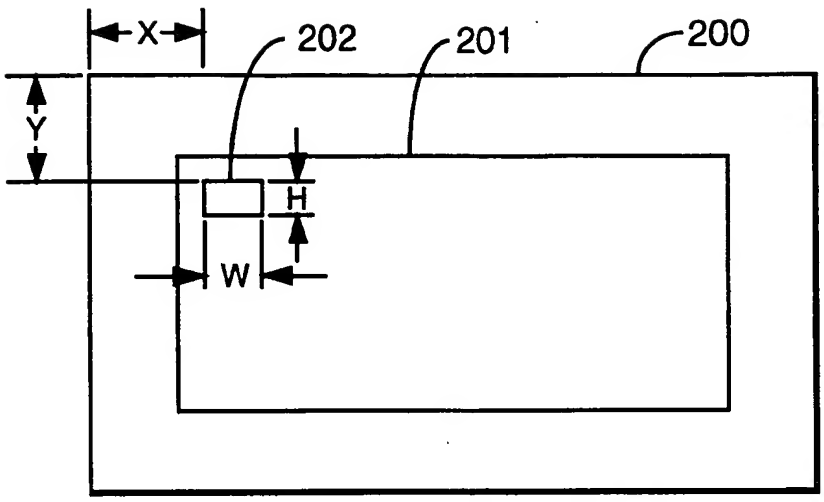

FIG. 2A

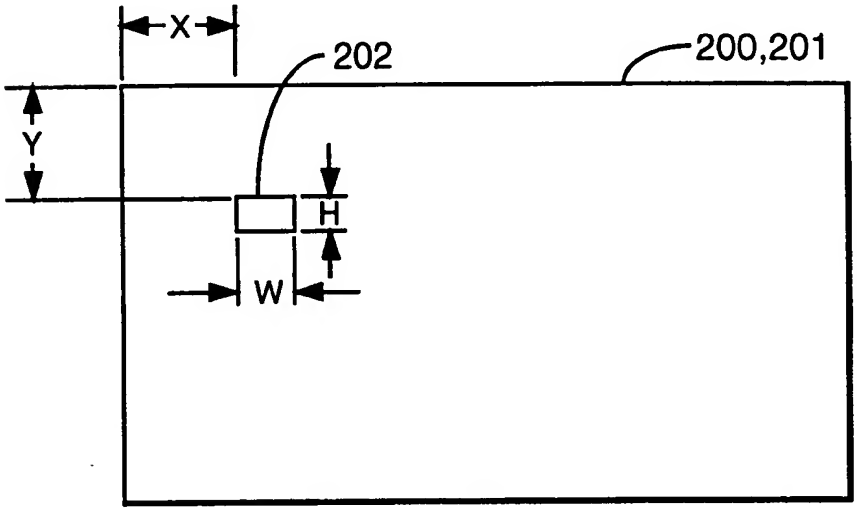

FIG. 2B

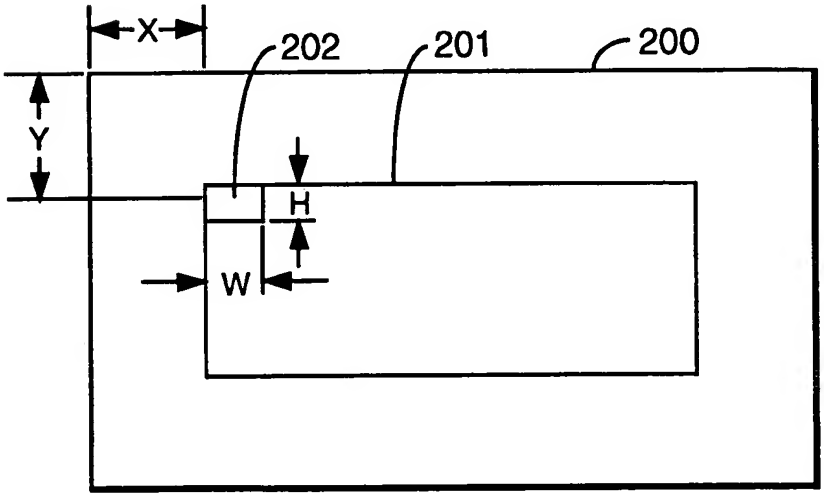

FIG. 2C

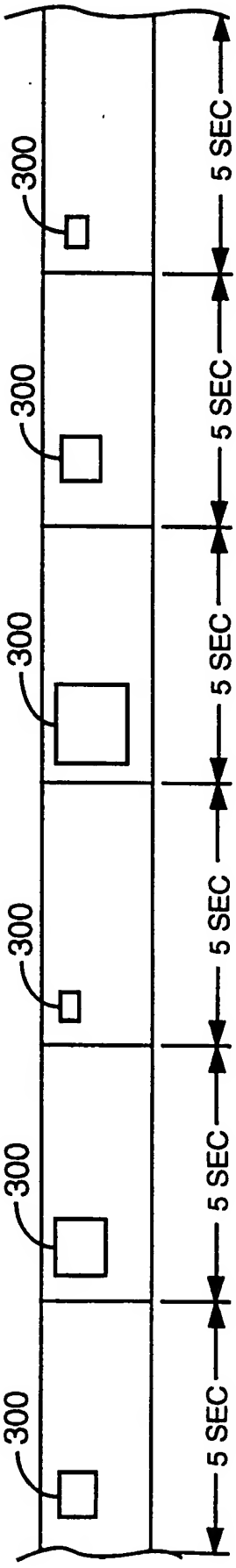

FIG. 3

INTERNATIONAL SEARCH REPORT

Intern ...al Application No
PCT/US 00/21003

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04N7/26

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04N A47L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
INSPEC, EPO-Internal, PAJ, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 902 591 A (SIGNAFY INC) 17 March 1999 (1999-03-17) paragraph '0016! paragraph '0043! ---	1-34
A	BRAUDAWAY G W: "Results of attacks on a claimed robust digital image watermark" PROCEEDINGS OF THE SPIE, 28 January 1998 (1998-01-28), XP002107541 the whole document ---	1-34
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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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'&' document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
23 October 2000	07/12/2000

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INTERNATIONAL SEARCH REPORT

Interr. nal Application No
PCT/US 00/21003

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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Information on patent family members

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